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Canada

SMALL HYDRO AND LOAD MANAGEMENT

Rendell Creek Ranch Community

RENDELL CREEK RANCH COMMUNITY

SMALL HYDRO

AND

LOAD MANAGEMENT SYSTEM

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EXECUTIVE SUMMARY

Rendell Creek Ranch, a typical small, remote community in southern British Columbia, was forced to install a small hydro-electric system to eliminate high diesel-fuel costs for generating electricity. To minimize the cost of the small hydro system, the community purchased and rebuilt an old 150 kW turbine and generator. Labour to install the system was donated by the community. With second-hand pipe and equipment, the completed system cost $30,000. The other alternative was a grid powerline connection 30 km away, at a cost of one-half million dollars.

Under the Remote Community Demonstration Program, Energy, Mines and Resources Canada (EMR) contributed funding towards: 1) a transmission line from the generator to a shingle mill, additional homes which were 3 km distant and future irrigated pasture, and 2) Load management equipment to fully use the electricity during low-streamflow and power output. Monitoring of the performance and benefits of the equipment was funded by EMR.

The load management equipment sequences the delivery of electricity to the various loads. Based upon community decided priorities, the load sequence (by priority) was: lights and outlets (including fridges and freezers), shingle mill, dishwasher, clothes dryer, hot water, house heat (upstairs house heat then basement); a total of 14 kW. Other loads were (by priority): second house dryer, hot water and house heat, school heat, dryer heat, hot water, building heat, community washhouse hot water, wash house space heat and school heat; a total of 31 kW. The peak output during 1987 was 70 kW, while the hourly peak electricity required was only 43 kW; the balance, 27 kW, was "dumped" by the electronic governor.

During late summer (September) and mid winter (February) streamflow decreased substantially. Initial estimates indicated that the expected output would be 10 to 15 kW, hence load management could ensure that all lights, fridges and freezers would continue to operate, and the "managed" (lower priority) loads would automatically be temporarily removed (or

sequenced if power were available). In fact, low water reduced the output to less than 9 kW, yet the load management equipment, combined with serious conservation efforts to disconnect non-essential loads, enabled the community to still use the small hydro generator. The shingle mill required 30 kW and was powered by the diesel generator during these times.

During periods of medium streamflow, ie 30 kW output, the shingle mill was operated, while non-essential loads were automatically "turned off", or "shed", to prevent over-loading the generator. At times of peak streamflow, all equipment could be operated. This was only possible for about four months, April through July.

The system rated size is 150 kW; the peak output during 1987 was 70 kW while the peak hourly load was only 43 kW.

The load management equipment operated successfully, while the transmission line enabled power to be delivered to two homes, future irrigated pasture and a sawmill. The system saves an estimated $1000/month of diesel-fuel; a two year payback for the small hydro system, and a further year payback for the load management equipment. The transmission line cost $10,000 and saved the installation of additional diesel generators at the other locations, which would have cost more over a four year period.

The present system is substantially oversized for existing needs and can function, when not water limited, as a system two or three times larger. This will provide ample capacity to meet future community growth.

The small hydro generator size could have been reduced by 25% to 35% by using load management techniques from the start. Sixty kilowatts of load management would have cost about $15,000, or $400/kw. A smaller and easier to build system would have resulted.

For other new small hydro systems, which typically cost from $1000 to $4000/kW, payback of less than one year would result by using load management equipment.

The project results are relevant to using load management equipment to reduce the size of diesel generators. The estimated payback due to fuel savings and smaller generators would be from two to four years, depending on the amount of generator "oversizing."

Résumé

Rendell Creek Ranch, petite localité éloignée bien typique du sud de la Colombie-Britannique, fut contrainte d'installer une petite centrale hydroélectrique pour éliminer les coûts élevés de l'électricité produite par générateurs diesel: Dans le but de réduire le coût de la petite centrale hydroélectrique, la localité acheta et remonta une turbine de 150 kW et un générateur usagés. La main-d'oeuvre requise pour installer la centrale fut fournie gratuitement par la collectivité. Le coût total de la centrale, dont les tuyaux et l'équipement furent achetés d'occasion, s'éleva à 30 000 $. L'autre solution était de débourser cinq cent mille dollars pour un raccordement avec le réseau dés lignes de transmission distante de 30 km.

Dans le cadre de son Programme de démonstration dans les collectivités éloignées, le ministère de l'Energie, des Mines et des Ressources défraya une partie de coûts 1) d'une ligne de transmission reliant le générateur à l'usine de bardeaux, à d'autres maisons situées à une distance de 3 km et à des pâturages qu'il fallait irriguer; 2) de l'equipment utilisé pour la gestion de la puissance appelée sur un réseau et servant à maximiser l'utilisation de l'électricité pendant les périodes d'écoulement faible et de production d'électricité réduite. Le rendement et les avantages de l'équipement furent étudiés aux frais du ministère.

L'équipment utilisé pour la gestion répartit le débit d'électricité selon les différentes charges. Etabli par la collectivité, l'ordre de priorité des charges était le suivant : lumières et prises de courant (y inclus les réfrigérateurs et les congélateurs), l'usine de bardeaux, le lave-vaisselle, la sécheuse à linge, l'eau chaude, le chauffage domestique (le rez-de-chaussée d'abord, puise le sous-sol); la consommation totalisait 14 kW. Par ordre de priorité, voici la liste des autres charges : la sécheuse de la seconde maison, l'eau chaude et le chauffage domestique, le chauffage de l'école, la sécheuse, l'eau chaude, le chauffage, l'eau chaude de la buanderie de la collectivité, le chauffage de la buanderie et de l'école; la consommation totalisait 31 kW. La production maximale fournie

en 1987 atteignair les 70 kW, tandis que les besoins un électricité par heure étaient de 43 kW seulement; le régulateur électronique "coupa" la différence, soit 27 kW.

Vers la fin de l'été, en septembre, et le milieu de l'hiver, en février, l'écoulement diminua sensiblement. Selon les prévisions initiales, le débit aurait atteint de 10 à 15 kW; par conséquent, le système de la gestion de la puissance appelée sur le réseau aurait pu assurer le fonctionnement de loutes les lumières, des réfrigérateurs et des congélateurs, et les charges "gérées" (d'importance moindre) auraient été automatiquement coupées, provisoirement, ou approvisionnées à intermittence s'il y avait eu de l'énergie en quantité suffisante. En fait, le bas niveau d'eau réduisit le débit à moins de 9 kW; l'utilisation de l'équipement de gestion de la puissance, conjuguée à de sérieux efforts destinés à limiter les charges non essentielles, permirent quand ,méme à la collectivité de contineur à utiliser le petit générateur hydraulique. Pendant ce temps, un générateur diesel alimentait en énergie l'usine de bardeaux dont la consommation s'élevait à 30 kW.

Pendant les périodes d'écoulement moyen, c.-à-d. de débit égal à 30 kW, l'usine de bardeaux fonctionnait, alors que les charges non essentielles étaient automatiquement éliminées ou "délestées" pour empécher la surcharge du générateur. Au cours des périodes d'écoulement maximal, tout l'équipement pouvait fonctionner, ce qui était possible pendant quatre mois seulement, d'avril à juillet.

La centrale est calibrée à 150 kW; le débit maximal pour l'année 1987 était de 70 kW, tandis qua la charge horaire maximale n'atteignait que 43 kW.

L'équipement du système de gestion de la puissance appelée sur le réseau fonctionna bien pendant que la ligne de transmission alimentait en énergie deux maisons, des pàturages qu'il fallait irriguer et une scierie. La centrale permet d'épargner 1 000 $ par mois en diesel; ceci représente un amortissement de deux ans pour la petite centrale hydraulique et d'une année additionnelle pour l'équipment de gestion de puissance. La ligne de

transmission coùta 10 000 $ et rendit inutile l'installation de générateurs diesel supplémentaires aux autres endroits, ce qui aurait été plus onéreux pendant une période de quatre ans.

Le centrale actuelle est surdimensionnée et peut fonctionner à une capacité deux ou trois fois plus grande quand il y a de l'eau en quantité suffisante. Cela suffira amplement à répondre aux besoine grandissants de la collectivité.

L'importance du petit générateur hydraulique aurait pu étre dimunée de 25 à 35% si les techniques de réglage de la puissance avaient été utilisées dès le début. Soixante kilowatts de gestion de la puisssance appelée sur un réseau auraient couté environ 15 000 $, soit 400 $/kW. Une centrale plus petite et plus facile à construire en aurait résulté.

L'équipement de gestion de la puissance appelée sur un réseau permettrait d'amortir en moins d'un an le coùt des nouvelles petites centrales hydroélectriques, lequel varie habituellement entre 1 000 et 4000 $/kW.

Les résultats obtenus démontrent que l'équipement d'utilisation de la gestion de la puissance permet de dimineur l'importance des génerateurs diesel. L'amortissement résultant des économies de combustible et de la taille réduite des génerateurs serait de deux à quatre ans, selon l'importance du surdimensionment du générateur.

ACKNOWLEDGMENTS

The Rendell Creek Ranch Community Small Hydro and Load Management project was based upon a truly "community" effort. Families and single people helped to put this hydro system together and make it the success that it is. They contributed generously in procuring materials, physical labour in laying pipe, welding and powerhouse construction. Some members made financial gifts to this project, making it all possible. Other members supported the effort while various technical people, both residents and consultants, provided direction and solved design and installation problems. Particularly Stan Dyck and Elroy Pankratz carried a great deal of the work load.

Energy, Mines and Resources under the Remote Community Demonstration Program contributed to the transmission lines and load management equipment (by Thomson and Howe) to fully use the electricity generated.

Doug MacDonald was an inspiration to the Rendell Creek Ranch community because he also built a hydro system.

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1. CONCLUSIONS

The value of small hydro power displacing diesel fuel was $13,500 per year. The hydro project cost $30,000 (not including labour); therefore the payback was less than 3 years. The value of unused electricity at 5 cents/kWh was $8,000.

The small hydro plant could have been reduced to 35 kW from 150 kW (and still operate the shingle mill). This could have saved about $15,000, equal to the load management cost. A smaller system would have been very much easier to install with smaller and lighter components.

Water flow in the stream was not dependable throughout the year. Power output varied from less than 9 kW to 70 kW as a result.

Load management, both electronic and manual, enabled the community to operate despite reduced streamflows and power output.

Electronic load management did not work during lowest streamflows, November through February.

The existing 150 kW plant (70 kW output in 1987) has an "equivalent size" as a result of the load management equipment. A hypothetical 35 kW plant with load management would be "equivalent sized" to the present plant, (with at least a 70 kW output); so too the present plant is equivalent to a larger system as a result of the load management equipment. This equivalent size is in the order of 125 kW. Thus considerable community and other load growth will be possible.

Given the present streamflow (with limited winter output, November through February) over a full year there would be about 10 kW of "managed" power available from April to September, plus five kW March and October. The annual value of electricity a 5 cents/kWh would therefore be $2000. The capital cost savings of load management are even more significant.

A hypothetical plant could be re-sized from the 43 kW maximum load to 25 kW maximum demand (without the shingle mill), or almost one half. At a cost savings of perhaps 1/3, and at a conservative cost of $1000/kW (this project with some allowance for labour), the capital savings would be about $12,000; roughly the cost of the load management equipment. (This includes the effect of low water, where power output is so limited that the load management equipment does not work from November through February.)

For Rendell Creek Ranch, where the real output peaked at 70 kW, the system could have been sized to 35 kW with load management. Expected capital savings by reducing from 70 kW to 35 kW would be perhaps 50%, or about $15,000. Again this would have equalled the cost of a smaller system including load management. The smaller system would have ben very much easier to install; nearly all components would have been 1/3 to 1/2 the size and weight.

The annual value of the electricity produced is considerable. Over the year the average load is about 16 kW; low because of water-limited winter output of about 9 kW (or less). At diesel fuel prices of 30 cents/L (10 cents/kWh), this electricity would have cost $13,250 (in diesel fuel), or about $1000/month. Thus for $30,000, the system paid for itself in less than three years. If fuel prices increase, the community is protected. Also, there is power available to expand.

The value of the unused electricity is also considerable. Typically, as during March, although 70 kW was produced, only 30 kW was needed. Over the year, this unused electricity amounted to over 160,000 kWh, worth $8000 at 5 cents/kWh, the equivalent price from a provincial utility, or if diesel generator produced, would be worth $16,000.

These results are from the performance of the system during 1987 only. In fact, with larger electrical loads as a result of a growing community, new users for power, or possible sales to neighbours, the existing system would be able to function as a much larger "equivalent sized" system. Just as the 70 kW output could have been met by the much smaller hypothetical

25 kW system, (with load management), so to would the 70 kW output be equivalent to perhaps 100 or 125 kW system, enabling considerable community and other load increases (when streamflow permits), without increasing the generator size.

This "equivalent system" provides most of the benefits of a larger system, without the cost; and is due to the load management equipment. Low water will of course still limit winter output when a diesel generator would be needed.

2. OBJECTIVES

The specific technical objectives of installing and monitoring the load management equipment were as follows:

- Observe and record the automatic reduction in peak loading below the maximum plant capacity, hence allowing system expansion without enlarging plant capacity.
- Observe and record the reduction in peak loading that will be forced by the management equipment as water availability decreases in late summer and winter.
- Observe and record the transfer of peak loads to other periods of the day, while maintaining system loading near the maximum available generation for extended periods, ie peak shedding. (This action allows a delay in meeting loads that were removed from peak loading periods. It is of interest also for potential diesel installations, since it will tend to maintain high engine loading for better fuel efficiency and equipment life).
- Observe the seasonal and daily change in system loads and the reaction of the load management equipment to these changes.
- Determine the value of diesel fuel saved and evaluate the economics of the system.
- Evaluate the possible reduction of size available as a result of load management equipment.
- Prepare a report on the technical and financial results.
- Disseminate the results to other diesel-fuel based communities and small hydro developers.

3. INTRODUCTION

3.1 Community Description

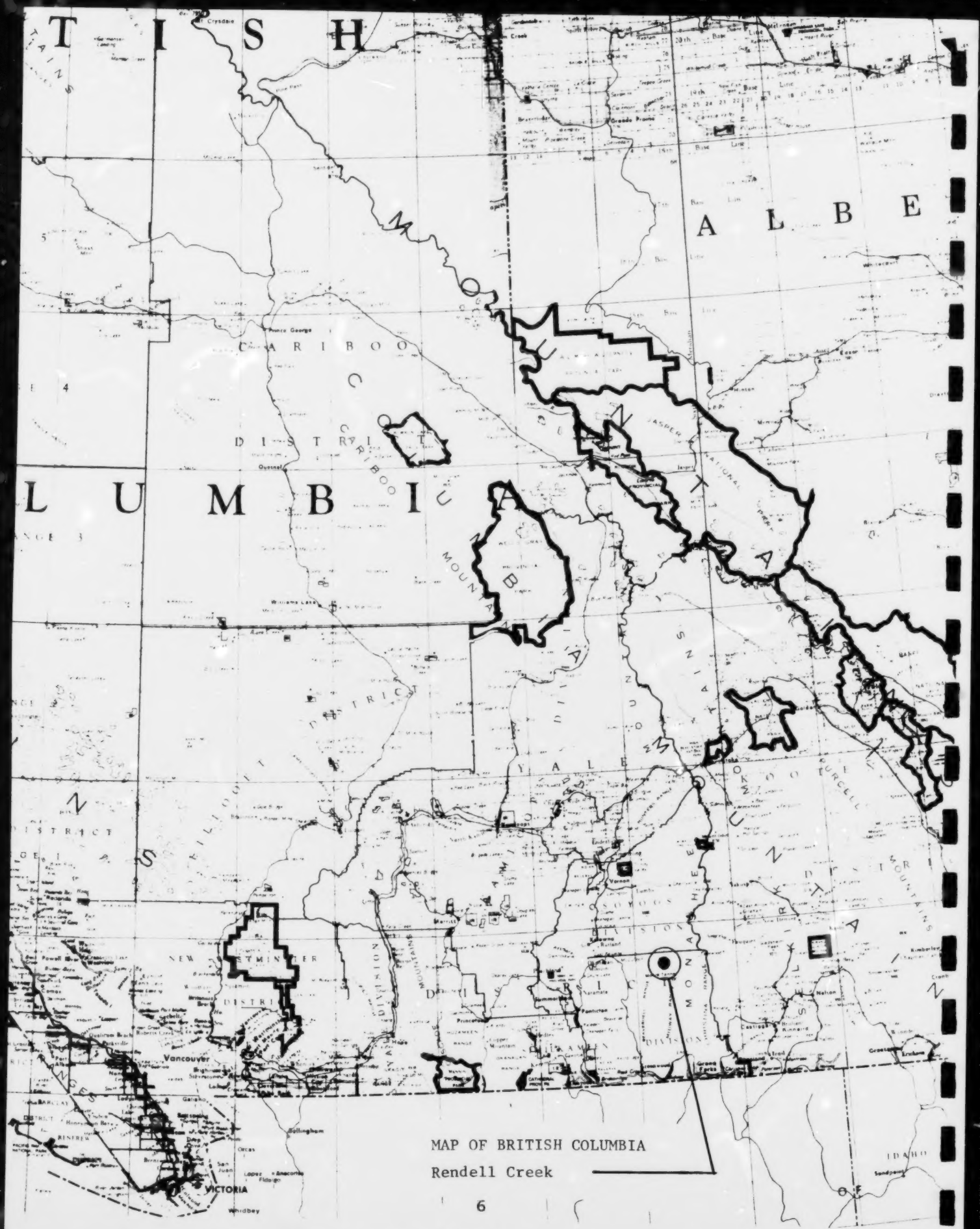
Rendell Creek Ranch community is located in a remote valley in the southern interior of B.C. (see map)

The property is an 80 acre parcel of land, it has 15 log cabins, four of which have been enlarged and plumbed. The large school house is hexagon shaped, made of logs as are the laundry and washhouse facilities. Outbuildings consist of 3 barns for horses, sheep and chickens. (see sketches).

The community has been in operation since 1982; its purpose is to provide accommodations for large and small groups for retreats, as well as provide a place for individuals to come for a time of rest and rehabilitation.

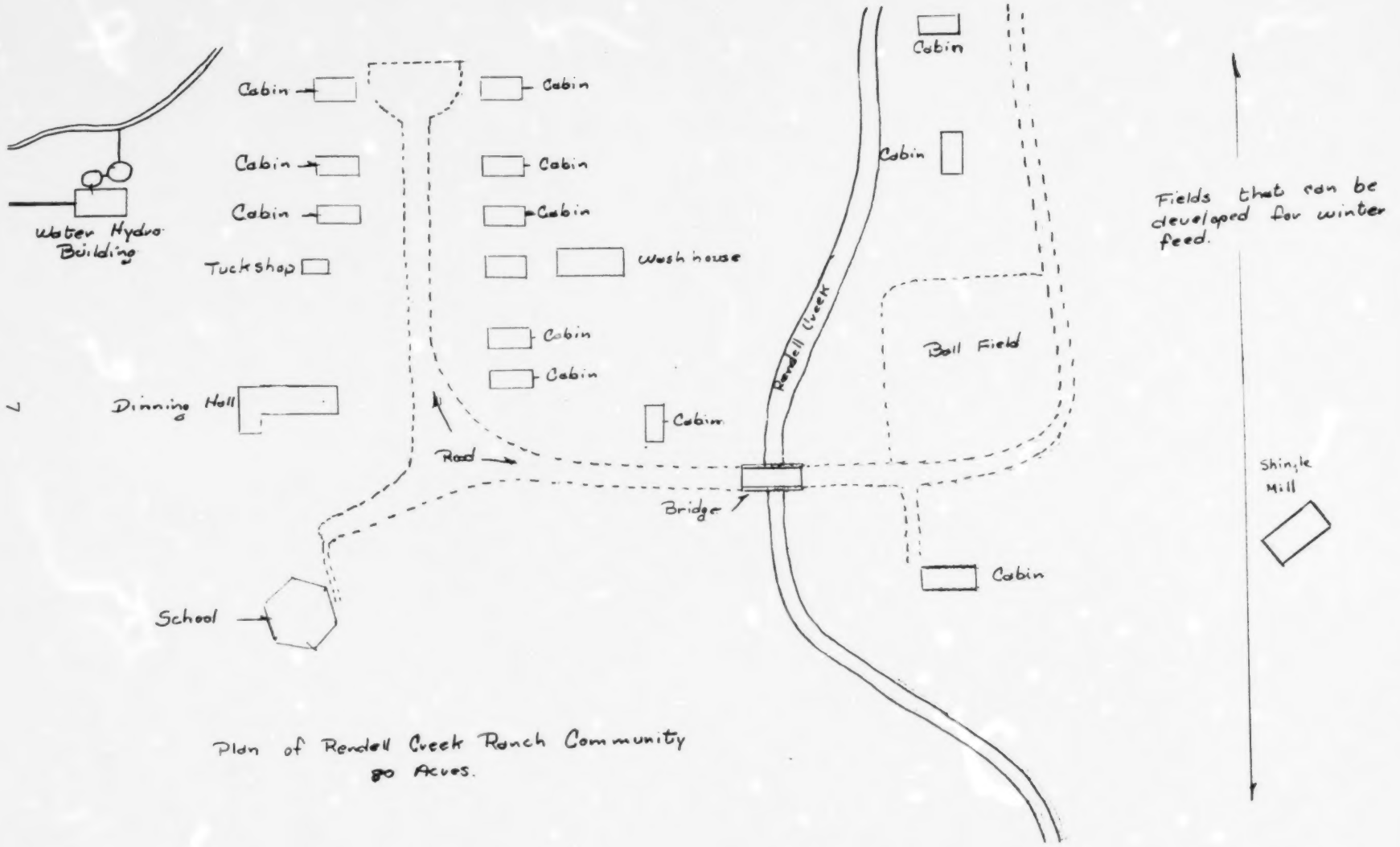
Because of the remote location, electricity was provided by diesel powered light-plants, until the cost of fuel became unbearable. Alternatives were examined: West Kootenay Power was contacted but because their grid was 30 kilometers down the valley it was too uneconomical. The other alternative was to develop an independent power system; so began the search for a nearby stream that had potential.

Immediately east of the community, Cochrane creek flowed down from over 2500 metres in the mountains. The stream had year-round flow although it dropped considerably in late fall and in late winter. Two other streams were investigated; one 10 km south which could have been developed with other ranchers was considered too distant; the third stream is 2 km north, has a smaller watershed but can be developed in future. None of the streams had lakes or storage while steep terrain prohibited installing substantial impoundments. Any system was therefore run-of-the-river and would be subject to seasonal flow variations.

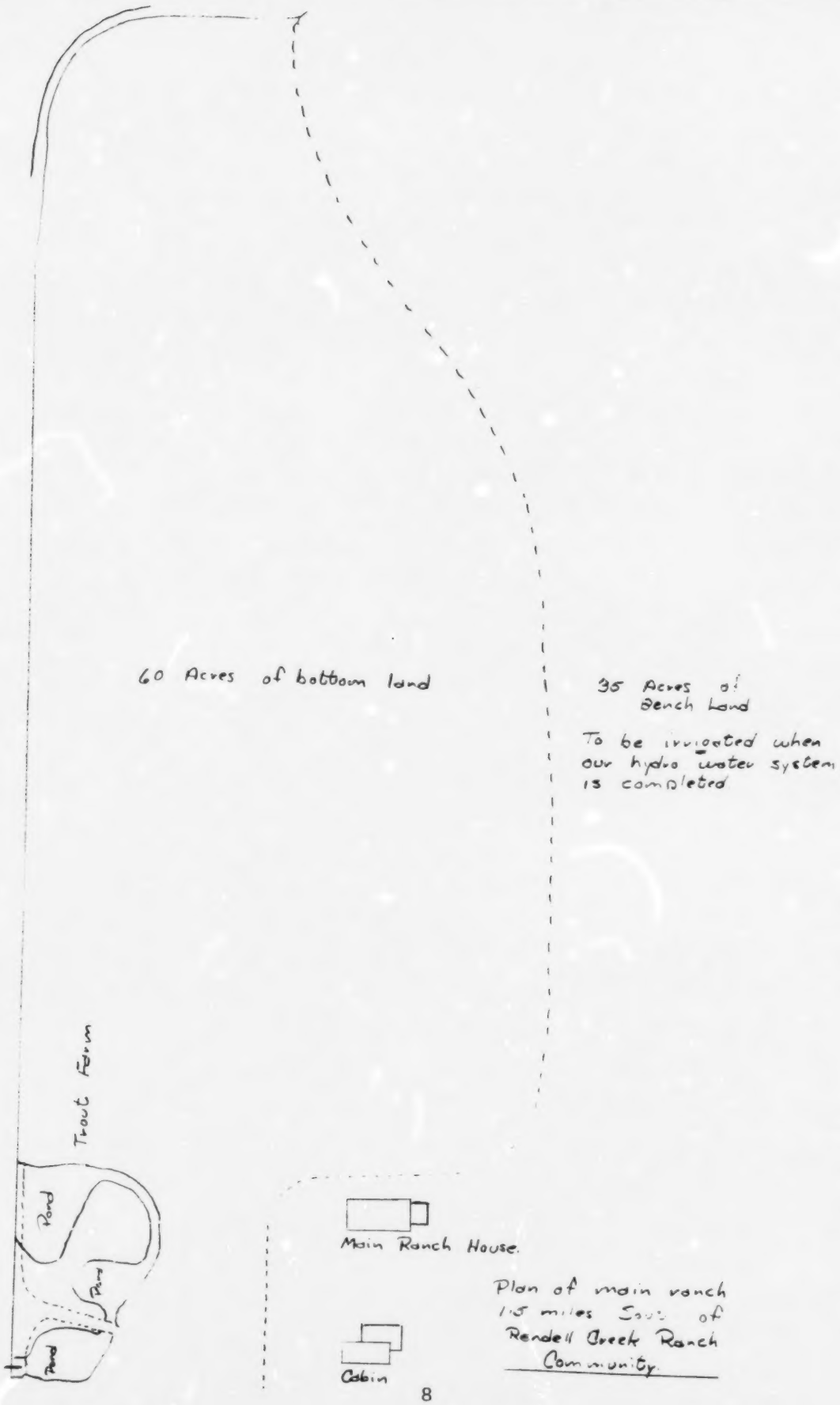


MAP OF BRITISH COLUMBIA

Rendell Creek



Plan of Rendell Creek Ranch Community
80 Acres.



Plan of main ranch 1.5 miles South of Rendell Creek Ranch Community.

Cochrane creek diverged from a former course at about 160 metres above a powerhouse location, a natural location for the intake and a log dam for a small settling pond. Living beside the stream for several years allowed the stream to be assessed for flow and power; enough for most of the year to provide power to several homes and community buildings.

3.2 Small Hydro System

Installing the hydro system was no small task. However the one big plus was a group of people willing to pool their resources and work together to see this project become a reality. It was the Ranch Manager's responsibility to work out costs and locate the needed equipment. It was a forgone conclusion that this equipment would have to be used (second hand) to make it affordable. The generator was secured from neighbors who at one time had planned to install it but thought the cost too high. This equipment had powered the town of Nakusp at one time in the early 1900's.

The 2800 feet of 10" steel pipe became available from the newly complete Revelstoke dam site. Shutoff valves, couplings and some additional pipe was exchanged for two truck loads of logs for firewood. Used transformers, insulators and pole hardware were purchased from West Kootenay Power. High voltage transmission wire was located at a salvage dealer in Richmond, B.C. The original estimated cash outlay was $27,500. The completed cost was approximately $30,000, not including labour.

It took approximately one year from the beginning of the hydro project until the system was turned on. Power is supplied not only to the community but also to the main ranch, two miles down the valley.

3.3 Electrical Load and Use

All cabins, homes, school, laundry, bathrooms and barns are serviced with 24 hour power. The school, laundry, three homes and three cabins are supplemented with electric heat. Electric heat can use surplus and night time available power to replace wood-fueled heaters with a much safer heat

source. (Shortly before the installation of the load management related electric baseboard heaters, the large kitchen and dining hall burned to the ground early one morning, despite routine night-time inspections of wood heaters).

There are eight washer and dryer hookups. A shingle mill was also operated. Projected use for the future is irrigation of hay fields, heated greenhouses, and raising trout.

The Rendell Creek Ranch power system is divided into two physical areas. The first area includes the powerhouse as well as most of the community buildings and the shingle mill. The second area at the end of the powerline includes the ranch manager's house as well as another house and a future irrigation pump.

3.3.1 Residential Loads

Residential loads are contained in 9 houses and consist of the following loads. (This is the approximate situation during the period of the survey except when special efforts were made to manually reduce the load during low water).

RESIDENTIAL LOADS

No.	Description	Unit Load	Peak Load	Duty % On	Average Load
10	refrigerators	400W	4000W	50%	2000W
24	deep freezes	400W	1600W	50%	800W
3	water pumps	600W	1800W	5%	90W
4	dishwashers	400W	1600W	5%	80W
3	dryers (electric)	5000W	15000W	5%	750W
100	incandescent lights	60W	6000W	10%	600W
10	fluorescent lights	40W	400W	20%	80W
4	hot water tanks	3000W	12000W	33%	4000W
6	baseboard heaters	1500W	9000W	33%	3000W
	TOTALS:		51400W (51.4kW)		11400W (11.4kW)

3.3.2 Community Loads

The community loads are mainly concentrated in the area of the powerhouse and consist of a school building, the powerhouse itself, a combined washroom and laundry building, and several minor buildings and sheds.

COMMUNITY LOADS

No.	Description	Unit Load	Peak Load	Duty % On	Average Load
1	refrigerator	400W	4000W	50%	200W
1	deep freeze	400W	1600W	50%	200W
3	washers	400W	1200W	10%	120W
1	dryer (electric)	6000W	6000W	5%	300W
25	incandescent lights	60W	1500W	10%	150W
10	fluorescent lights	40W	400W	20%	80W
1	hot water tank	3000W	3000W	50%	1500W
7	baseboard heaters	1500W	10500W	50%	5250W
	TOTALS:		23400W (23.4kW)		7800W (7.8kW)

3.3.3 Industrial Load

The industrial load is only at the shingle mill, and consists of a 30 hp shingle saw and some lighting. Average load is 2% or less of rating, or 500 watts. Peaks could reach 40 kW if operated to the maximum possible loading or if it became jammed.

INDUSTRIAL LOAD

No.	Description	Unit Load	Peak Load	Duty % On	Average Load
1	30 hp shingle saw	25 kW	40kW	2%	500W

The potential future load for the existing buildings could consist of ten fully equipped residential homes with peak loads of 15 kW each and average energy requirements of perhaps 4 kW each. The community and industrial loads can be considered in the future to increase their duty, meaning that the facilities would be used more fully for longer periods. In addition,

surplus energy from the hydro plant not otherwise used could be used in the future for heating water to a trout hatchery. All these uses for electricity presuppose sufficient water, otherwise there would be little use installing additional loads.

The combined effect of the loads and the operation of the load management equipment is discussed in section 3.6.

The electronic governor also involves loads. The governor uses immersion water heaters of total equivalent size as the generator as a "load dump". This produces heat, presently rejected, which could be used as desired - hot tub etc. As useful loads are added to the system, such as building heat, the governor automatically turns off an equivalent load at the load dump. Similarly, as useful loads are turned off the system, the governor compensates by turning on identical loads at the load dump. This does not use all of the water and power as efficiently as possible, but it maintains a very steady frequency and stable electrical system. It would have been possible to have the governor control the water flow, but this would have been an additional refinement and expense to the community, which had limited capital at the time.

3.4 Load Management Principles

Electrical load management is used to reduce the peak requirement for electricity (or peak demand), thus creating a more even load. At Rendell Creek it was done electronically. The electricity is switched on or off in a pre-determined sequence, among the various appliances or uses. A priority is established for each use to determine the sequence. The priorities were: electric lights and outlets, fridges, freezers, dishwashers, clothes washers, dryers, stoves, water heaters, and building or space heat. Revenue-earning uses such as a sawmill or shingle mill may also be assigned a high priority because of the importance of the revenue.

Once the priority is established, the electronic controller automatically keeps track of how much power is available from the generator, how many appliances or uses are on and how much power they require, and what the priority is on each use. If a high priority use is switched on, the controller turns off a lower priority use so that the generator does not get overloaded. The frequency of 60Hz is used to sense the load on the generator; adding load will try to overload the generator, hence slowing it down and reducing the frequency. Turning a high priority load off will reduce the power needed from the generator, it will try to speed up and the controller will then switch a lower priority load on.

For example, suppose lights, water heater and building heat are all on, and turning on a clothes dryer would overload the system. The load management system senses the impending overload and would turn off the building heat and water heat until the clothes were dried and the dryer goes off. Then the water heat would come on again, and if enough power were available, the building heat. When the water heater was sufficiently hot to turn itself off, the available power could be directed to the building heat. It is this clever sequencing and movement of electricity to maintain a steady load on the generator which is the essence of load management. Of course it could all be done manually, and may be necessary during extremely low water, but it is much more sensible to have it done automatically.

The load management system therefore enables the electrical generation system to provide power in a way such that it performs like a much larger system; the overall capacity is effectively increased, since the normal effects of peak electrical loads do not overload the system. Conversely, a system can be designed to be much smaller, and cheaper to begin with, since the "peak" or maximum power needed is automatically reduced. Load management is well-suited to "run-of-the-river" small hydro systems, where the output may be limited by the available water in the stream. With sometimes dramatic seasonal changes in streamflow, and hence available power, the generator with load management can automatically adapt to use the power in the best way, by priority.

3.4.1 Frequency Controlled Load Management

The use of frequency monitoring for controlling the operation of load management has two major advantages and one major disadvantage over equipment using a pre-set maximum peak. The disadvantage restricts its use to only small, remote power systems:

1. The managed loads will automatically track the available power generated, allowing maximum possible use of the generator under all conditions, and without overloads.
2. No monitoring of power demand levels is required at any point in the system since frequency is available anywhere on a power system. As many of these load management devices can be installed as desired, and at any location desired, no matter how remote to the generator. (This was done on a diesel system at Strathcona Park Lodge in a separate project).
3. Since the equipment must be able to see the frequency change in response to changes in loading, this type of control will not work on large utilities, where the frequency will remain unaffected by the small loads of concern to us here. This type of equipment is specific to remote, non-utility connected power systems only.

3.4.2 Load Management Advantages

The advantages of adapting proven load management techniques to small power systems are potentially even greater than has been demonstrated on utility connected facilities for the following reasons:

1. Allows a smaller capacity power generation plant, hence reducing initial capital costs, weight, size, and maintenance cost, and also placing less concern on water availability.
2. Allows better use of the water resource available by extracting the maximum usable energy from the generator at all possible times. (If a diesel generator is used, then higher fuel efficiency and lower maintenance can be obtained by higher loading, as at Strathcona Park Lodge).

3. Back-up generation equipment may be considerably scaled down in size by assuming that some, or all, managed loads may be temporarily removed from the system.
4. Load management can be an alternative to installing more generation capacity when expanding a system.
5. Load management can prevent an overload on one generator, providing time while a second generator is brought up to speed and synchronized to the first.

3.4.3. Categories of Interruptible Load

The major difficulty with load management is the selection of suitable loads. Loads that may be considered fall into the following categories:

1. Loads that have a non-electric alternative. Any kind of heating load can be arranged to be of this type. These loads may be interrupted indefinitely.
2. Loads with a storage capability. Water heating would be of this type. Operations that can be delayed during power curtailments and later caught up with are also of this type. Eventually, these loads must be turned on to avoid complaints.
3. Luxury loads that can be done without.

Examples of Manageable Loads

1. Deep freezes and refrigerators
2. Domestic washers and dryers.
3. Water heating.
4. Electric heating elements (with a backup heat source)
5. Water or sewage pumps, with holding tanks for storage
6. Air conditioning.
7. Sauna heaters
8. Swimming pool heaters
9. Soil heating cables or greenhouse heating
10. Irrigation or stock feed pumps (especially with storage)
11. Snow melting cables in driveways

3.4.4 Concept of Priorities

The equipment installed at Rendell Creek Ranch was designed to have eight priorities of control. Each load managing computer was equipped with eight relay control lines that could be connected to relays on loads. Power permitting, the highest priority control line would always be turned on first before any others, and turned off last, after all others had been turned off. The more important loads were connected to the highest priority lines, and less important loads to the lower priority lines. This arrangement would ensure that, of the controlled loads, the available power would always go to the most valuable use first, and less important loads would be turned on only if sufficient power was available to turn them on as well as the more important loads.

3.5 The Installation of Load Management at Rendell Creek Ranch

Due to financial constraints, complete residential load management with electric heating was installed at one house only. This house was then separately monitored. The results of this load management operation were also recorded at the system monitoring location. The control provided in this house is as follows:

Priority	Description	Load
Highest	- fridge + deep freeze	800W
2nd	- dishwasher + provision for 2nd fridge	800W
3rd	- dryer (heating element only)	6kW
5th	- hot water	3kW
7th	- upstairs heat	1.5kW
8th	- downstairs heat	2.5kW
TOTAL load under management at this house =		14600W, or 14.6kW

Other load management was installed on the system at several other locations as follows, in order of priority. The effect of this load management was monitored only by the system monitoring equipment at the powerhouse.

Priority	Description	Load
4th	- dryer heat at another house	6000W
6th	- hot water and electric baseboard heat at same house	2.5kW
9th	- school heat	3kW
10th	- dryer heat	6kW
10th	- hot water	1.5kW
10th	- baseboard	1.25kW
11th	- washhouse hot water	3kW
12th	- washhouse space heating	4.5kW
13th	- schoolhouse heat	3kW

TOTAL load under management elsewhere is 30750W, or 30.7kW

TOTAL managed load for both areas 14600 + 30750 = 45350
= 45.3kW

3.6 Effect of Load Management on the System Spare Capacity

Without load management, the maximum residential/community load (from section 3.3), plus the 40 kW peak from the shingle mill is 115 kW (see table below); in excess of the maximum plant capacity, without considering possible low streamflow and low power. This probably required that the users made certain that some loads were not turned on when the shingle mill was operated, no matter how much water was available. Also to some extent, the assumption could be made that not all loads would be turned on simultaneously.

Residential peak load	51400	51.4 kW)	
Community peak load	23400	23.4 kW)	74.8 kW
Shingle mill peaks	40000	40 kW)	
TOTAL peak load without management	114800	114.8 kW	

By installing 45350 watts (45.3 kW) of load management (section 3.5 above), the peak load above has been reduced from 74800 watts (74.8 kW), without the shingle mill, down to 29450 watts (29.5 kW), (74.8 - 45.3), or 69450 watts (69.5 kW) peak with the shingle mill in full production. This means that for generator output above about 30 kW (without the shingle mill working), no overload is likely at any time. If the shingle mill is

operating, then the generator output would have to be kept over 60 to 70 kW to prevent potential overloading. Additional load management would be needed if water availability were below these levels.

There must also be enough energy available from the plant to satisfy the expected daily energy needs of all loads. In other words, even though a load may be turned off temporarily to prevent an overload, we would like it to be turned on soon enough to prevent hardship or inconvenience to the users. If we take the estimated energy requirements from the right hand columns in Section 2.3, we get the following:

Residential energy requirements	11400W	
Community energy requirements	7800W	
Shingle mill	500W	
TOTAL average energy requirements	29700W	or 29.7 kW

Hence, there should be sufficient energy from the plant even at the 30 kW level to satisfy the average energy requirements of the community. This energy requirement assumes average temperature with the existing electric heating only installed, so preferably, there should be considerably more energy available in cold weather to allow full use of electric heating and reduce wood burning requirements. The amount of this additional heating energy will be either limited by the actual amount of installed electric heating, or ultimately, by the available capacity from the powerplant.

During 1987, the low winter streamflow limited the output (to 9 kW); at which point that the average annual power became about 19 kW.

4. PROJECT DESCRIPTION

4.1 Load Management Equipment

The following load management equipment was installed and monitored at the ranch manager's house:

- a Thomson and Howe Energy Systems Product "C" load manager, to control where the electricity would go;
- three Thomson and Howe Energy Systems single 10 amp relays, on small loads such as baseboard heaters;
- four Thomson and Howe Energy Systems Dual 30 amp relays, on larger loads such as the drier, and water heater elements;
- low voltage wiring inside the house from the product "C" load manager to the relay units. (Most of the relays were installed next to the breaker panel in the basement); and,
- 120 volt power wiring to the product "C", load manager.

The following load management equipment was installed at a second house adjacent to the monitored house, but only monitored by the system monitoring at the powerhouse:

- one four conductor aerial cable from the monitored house to the adjacent house; and,
- two Thomson and Howe Energy Systems Dual 30 amp relays, to control large loads such as water heater elements.

An electronic load control governor was installed at the powerhouse, replacing the mechanical fly-ball governor previously used. This governor also had four levels of load management priority built into it, so aerial lines were strung to supply these control signals to additional loads in the vicinity of the powerhouse. This comprised:

- one Thomson and Howe Energy Systems Product "K2" governor.
- one water-cooled load dump fabricated on site, totalling 100 kW of load, controlled by the governor to eliminate surplus energy, hence maintaining constant 60 HZ system frequency.

- one Thomson and Howe Energy Systems Frequency Guard shut-down relay and holding solenoid. This device is intended to shut-down the turbine if the frequency deviates too far from 60 Hz due to equipment failure or generator overloading.
- several 4 conductor aerial cables linking the powerhouse, the school, the washroom, and an additional house for load management purposes.
- four dual 30 amp relays: 1 at the school; 2 at another house; 1 in the washhouse, to control the larger loads.

The priorities for each of these managed loads were chosen on the basis of the following criteria. The criteria were not absolute, and small deviations took place to simplify wiring or to save installation costs. The priorities were:

1. Highest - loads that would cause loss if left off for a relatively short time, hence refrigerators were connected to the maximum or highest priority step.
2. Second - loads that would cause a loss if left off for a slightly longer period of time were put on the 2nd priority, e.g. deep freezes.
3. Third - loads that are only operated for relatively short periods of time and not very often were given the next priority, e.g. Domestic dishwashers.
4. Fourth - loads that are user operated also but run somewhat longer and more often were given the next priority, e.g. Domestic clothes dryers.
5. Fifth - hot water heating.
6. Sixth - space heating, residential living areas.
7. Seventh - space heating, residential basements.
8. Eighth - space heating, community buildings.

5. MONITORING DESCRIPTION

Three B.C. Hydro rotating induction disk watthour meters were used at the three points in the power system that were monitored. Two of these meters were used on the 2400 volt 3 phase system at the powerhouse using current and potential transformers. The third was a single phase direct connected meter installed at the service entrance to the monitored house.

Each of these meters was supplied with a electrical pulse output, in each case indicating the passage of a certain number of watt-hours. These pulses allowed additional equipment to monitor and record the power transferred during predetermined intervals. The data, consisting of pulse counts, was recorded on cassette tapes every hour.

The problem of determining how much of the electricity being used was "managed load" was difficult to solve. The loads were too scattered and too many to individually monitor with recording watt-hour meters, and simply recording which priorities were turned on was not sufficient. There was no guarantee that any particular load, when allowed to turn on by the management system, was actually requiring power.

The problem was solved by turning all managed loads off once every hour. This was relatively easy to accomplish by programming the governor to reduce the system frequency by 1 Hz for 5 minutes every hour. The management computer(s) saw this as a sign of an overloaded system and removed all managed loads. By comparing the pulses received during this 5 minute period to the pulses received during the rest of the hour, the reduction in load could be calculated.

Two items of data that would have been useful were not recorded. The first of these is the amount of managed load turned off at any point in time, say every hour. To determine this amount, we would need to have a generator with sufficient capacity to turn all these loads on, and connect it to the system every hour, similar to the way the managed loads were

turned off by dropping the frequency. Since such a generator was not available, this factor can only be guessed at.

The other item of data is the "marginal priority". This is the lowest priority of load that the management system could turn on at any point in time. It was not possible to specifically record this data either, but an approximation is possible by looking at total interrupted load every hour and comparing this to total connected interruptible load.

The rest of the monitoring equipment consisted of two parts. The first item was a small computer custom programmed to receive pulses from the B.C. Hydro meters. This computer also monitored the system frequency, so it would know when the 5 minute under frequency period was entered every hour. The pulses would be accumulated in two separate counts, one for the 5 minute period when all managed loads were turned off, and one for the rest of the hour when the management system was allowed to operate normally.

The other part consisted of, in each of the three monitored locations, a battery-powered Campbell Scientific CR21 data logger with cassette tape recorder. These data loggers were used in part due to the in-house EMR availability, but also because of their ability to operate without mains power, and under adverse conditions of temperature, humidity and cleanliness.

Community and house total pulses for 55 minutes out of the hour, and demand for 5 minutes each hour, were logged as well as generator total pulses to measure electrical power production. The data loggers dumped the values to cassette tapes at each location. Local staff collected the tapes approximately every month and checked and replaced batteries if required.

Some data loss occurred due to low batteries, however overall reliability was sufficient. The community load and interruptible data were 90% complete for February through August 1987; the generator was 86% complete for February through June; the house was 90% complete for November 1986 through

June 1987. Some useful data were obtained from the fall of 1987, although the system was operated in a "brownout" condition due to low streamflow.

The data tapes were played through an Interface Terminal to create computer compatible data for processing with a Lotus 123 spreadsheet. This was processed to provide Total Output, Demand Load, and Interruptible power for the community and for the house. Also, Generator output and power to the Governor were determined. This hourly data was checked for completeness and inconsistencies and flagged where the data was doubtful. Output printouts and graphs of the hourly data were produced for reports (see Section 6 and Appendix B).

Time of day profiles were produced for the house and community power use. In all cases, data flagged as doubtful were not included in the analyses. Interpolation of data was made to "infill" missing data, in order to calculate the value of electricity, and for cost benefit analyses.

6. RESULTS

6.1 Technical

Four distinct operating modes during two seasons were identified. The modes were defined by high load or low load, and high or low generation, due to streamflow. The seasons were winter and summer. We wished to compare as many of these eight potential sets of data as we were able to obtain in order to observe the operation of the management equipment during different circumstances.

In each of the periods data were recorded and analyzed for:

1. Hourly values of generator output,
2. Hourly values of system demand load,
3. Hourly values of system interruptible load,
4. Hourly values of an individual house demand load, and
5. Hourly values of an individual house interruptible .

Data were analyzed to determine the operation of the management equipment on a averaged 24 hour basis, providing the following information:

1. Average kWhrs moved from peak periods to off-peak periods per day.
2. Typical daily profiles for demand load and interruptible load for this specific installation.

The data were also analyzed for seasonal performance and variation:

1. The minimum size of generator to supply these loads without load management, versus with load management.
2. Additional energy derived from the generator, due to the load management equipment allowing more complete utilization.

The following table provides a guide to the data that was obtained. Note that HL means high load (usually cold weather), HG means high generation (high water), LL means low load, and LG means low generation (low water):

	<----------TYPE OF RECORDING PERIOD---------->							
	<--------SUMMER--------->				<---------WINTER-------->			
DATA ITEM	HL-HG	HL-LG	LL-HG	LL-LG	HL-HG	HL-LG	LL-HG	LL-LG
Generator Total:	(1)		yes		(2)	(3)	yes	yes
Demand load:			yes				yes	yes
Interruptible:			yes				yes	yes
House:								
Demand load:			yes				yes	yes
Interrupt:			yes				yes	yes

(1) high load would have been cold weather or new loads i.e. irrigation
(2) high loads were not fully connected
(3) high load - low generation; loads were shed or manually turned off.

In addition to the data above, we recorded specific periods that were indicative of system operation and trends. Some of these were:

1. Transition periods, low to high water,
2. Transition periods, high to low water, and
3. Community response to changes in water supply for generation, adaptability of the users.

Data could not be obtained for all conditions due to:

1. The system loads were never high enough to obtain a high load figure when the generation was high.
2. When generation was low, it was so low as to prevent the load from being anything but low also. The variation of load between high and low periods was small due to fairly constant conditions.
3. When the generation was very low, the system was operated for extended periods of time in a brown-out condition, which largely prevented valid data collection.
4. Data was not available during the depth of winter in December-January, however, the generator output was apparently so low that the data would not of been of much use anyway.
5. No periods of low generator output were recorded during the summer.

6.1.1 Winter - Low Generation, Low Load Analysis

This data was from February 1987. Generator output was limited by low water to about 9 kW.

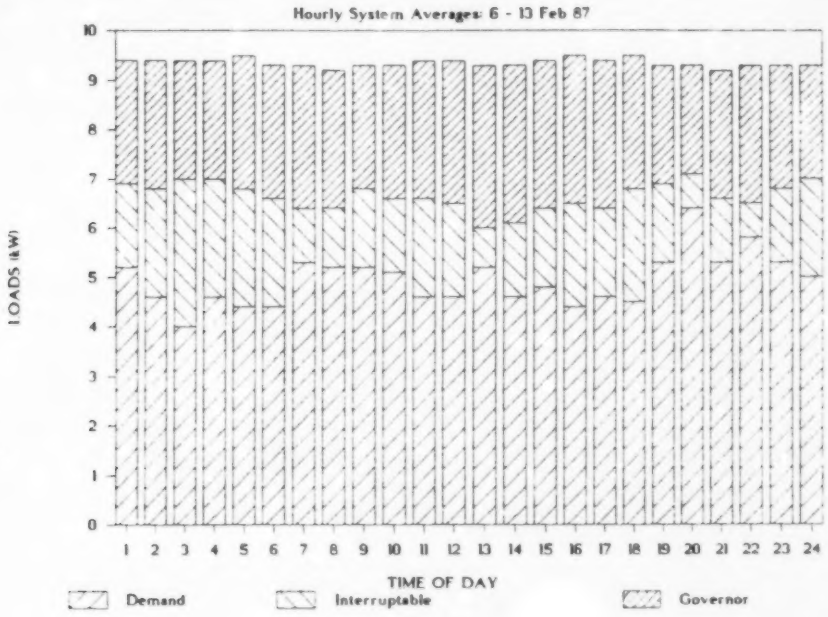


Figure 6.1

The Hourly System Averages for February 6-13, 1987, Figure 6.1, show that the governor load (the hatched portion at the top of the bar chart) reached a minimum level of about 2500 watts. This minimum level resulted from a combination of losses in the transformers supplying the governor, and the impact of constant fluctuations in system load. The frequent peaks of these fluctuations turned off managed loads, throwing the load onto the governor. Since 2 kW is a typical size of heating load, this was the approximate minimum governing load possible, assuming that correct frequency was maintained. During periods of the day when more fluctuations occur, for instance, at 8 AM and noon, the governor load can be seen to have increased slightly. The managed loads also gave up power to the demand loads as required, and so these loads reached a peak when the system was most steady and when the demand load was least. This can be seen at 3 AM as would be expected.

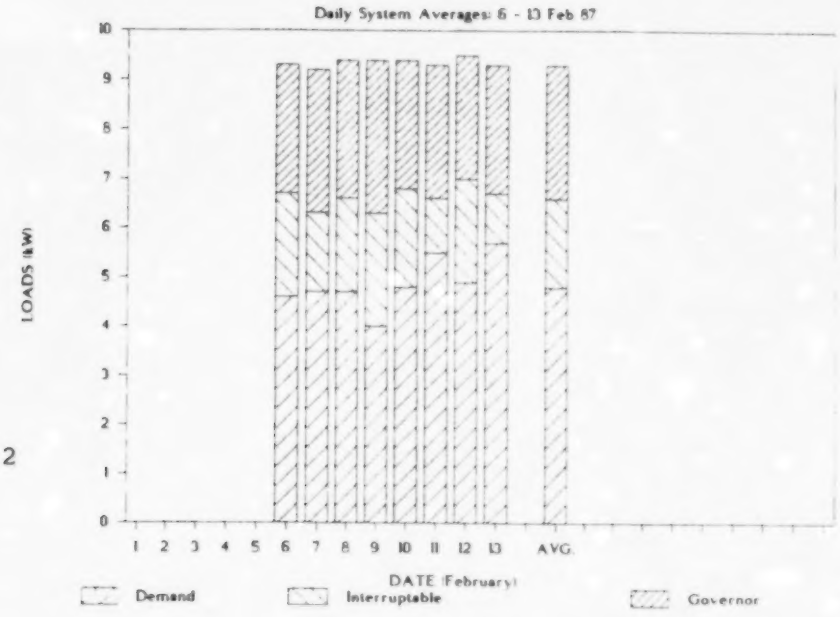


Figure 6.2

The Daily System Averages for February 6-13, Figure 6.2, show how the interruptible loads were maintained at the maximum level possible, keeping the above in mind. The daily deviation from the "average" interruptible plus demand power level was less than 300 watts or so, despite changes in demand loads of more than double this variation.

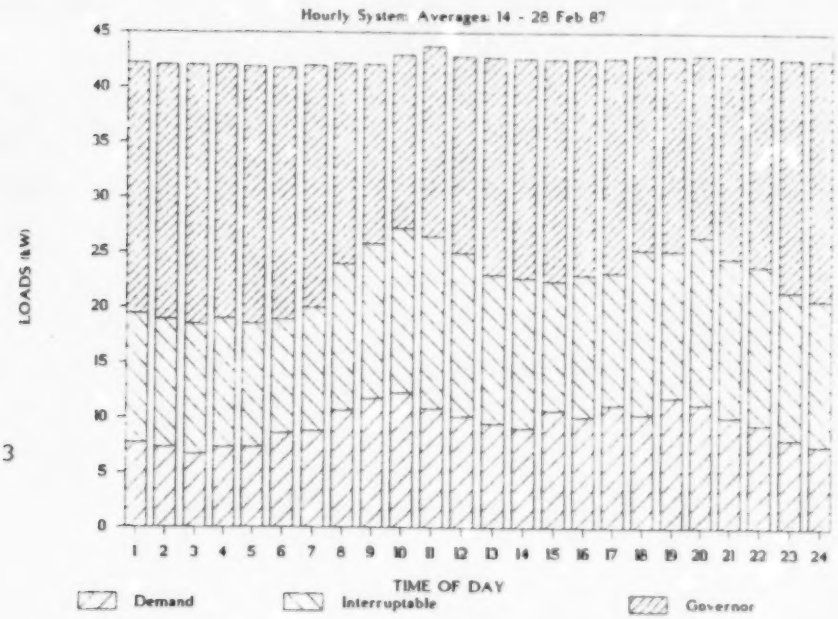
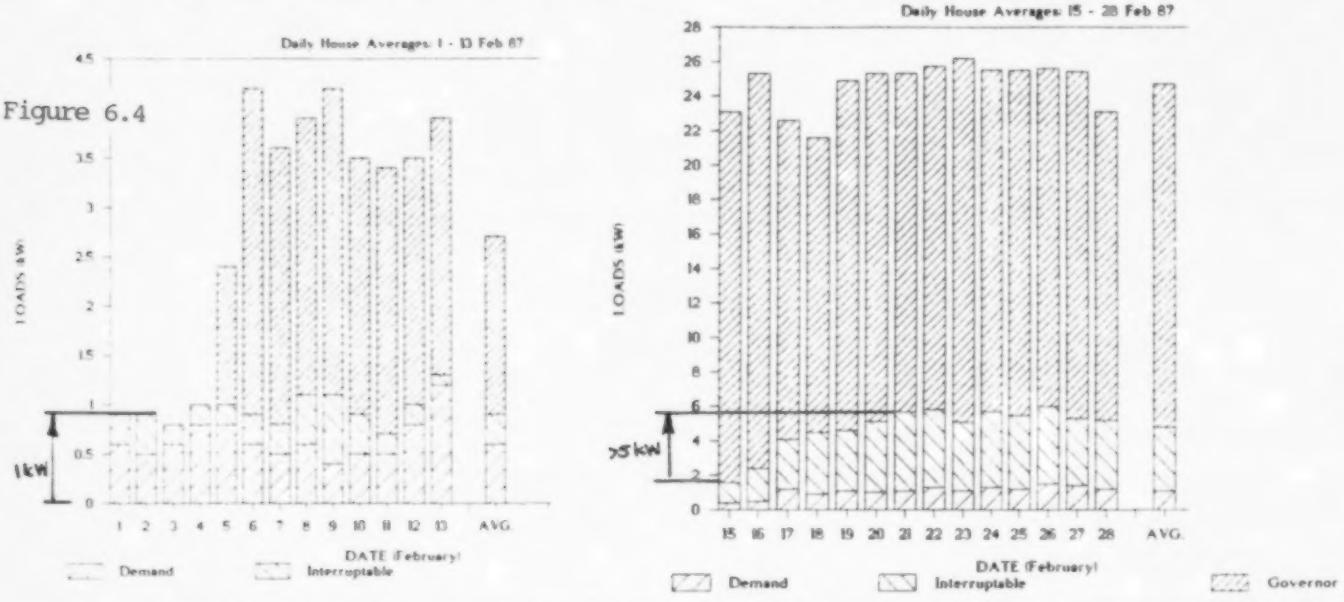


Figure 6.3

The Hourly System Average for February 14-28, Figure 6.3, shows that the interruptible load increased immediately from 2.5 kW to approximately 12 KW as soon as streamflow increased, allowing a nozzle change and thus increasing the generator output to 42 KW (between the 13 and 14 of February). Here the interruptible load remained constant at the maximum load connected, and all load variation is the result of daily demand load variations. The system now could have handled many more loads than were connected. Another interesting result of the increased generation is the gradual increase in load from 5 kW before February 13, to 12 kW by February 26, from the right hand side of Figure 6.4. Obviously, manual load management was being done during the period of low water, and the community took two weeks or so to adapt to the increased power availability.

Figure 6.4


Daily House Averages: 1 - 13 Feb 87
LOADS (kW)
1kW
1 2 3 4 5 6 7 8 9 10 11 12 13 AVG
DATE (February)
Demand
Interruptable
Daily House Averages: 15 - 28 Feb 87
LOADS (kW)
>5 kW
15 16 17 18 19 20 21 22 23 24 25 26 27 28 AVG
DATE (February)
Demand
Interruptable
Governor

The Daily House Averages data for the February 1-13 period, Figure 6.4, show the minimum power use enforced by the minimal power availability. Very few interruptible loads could turn on during these periods, averaging about 500 watts. Also, most of the interruptible loads were turned off anyways by the owners; this is proved by the impact of increased generation after the 14th. The interruptible load seen on the Daily House Averages for 15-28 February show a lag of several days before these loads increased to a more typical 5kW. This delay is not typical of the load management equipment, which would immediately take advantage of extra power being

it is indicative of the owners turning loads on manually as the increased generation was recognized.

6.1.2 Winter - High Generation, Low Load Analysis

This data was from March 1987, high generation (from high streamflow).

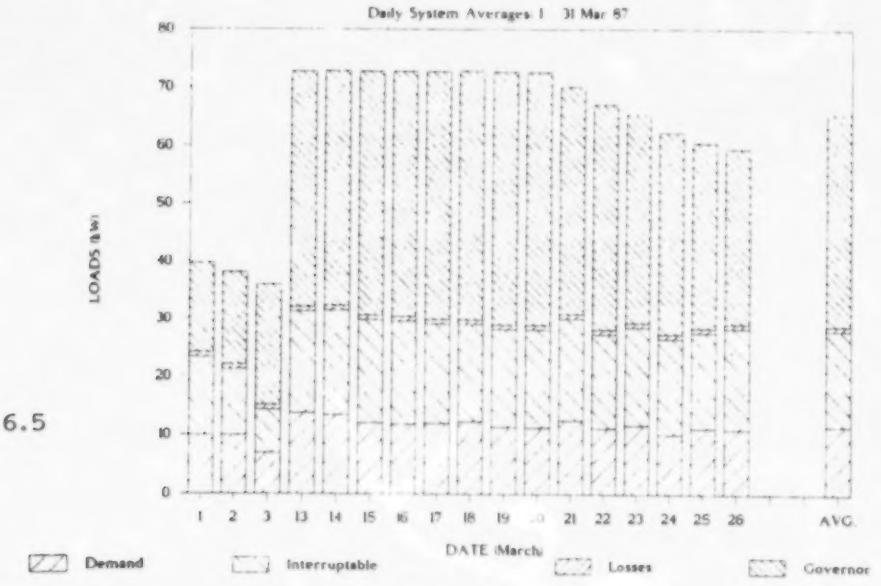


Figure 6.5

Figure 6.5 shows during March 1-3 that the load management equipment turned on all available loads and left them on. After March 13, if more electric heating loads had been available to be managed, an additional average energy of about 37 kW (70-33) could have been obtained from the governor's load dump. In this specific condition, the management equipment serves little function, so it's immediate value is minimal. If the shingle mill had operated, then the interruptible load could have provided additional power to the saw, but the surplus was so great that even this probably would have not been necessary.

Between the third and thirteenth of March, another nozzle change (with more streamflow) allowed the generation to be increased by a further 35 kW to over 70 kW. Since even the previous power was sufficient for all loads except the shingle mill, the impact of this additional power on the

interruptible loads was not great. An increase of 4-5 kW can be seen by comparing March 1-2 with March 14-21. The demand load increased slightly also, indicating that some loads were turned on as the users got used to having high generation again.

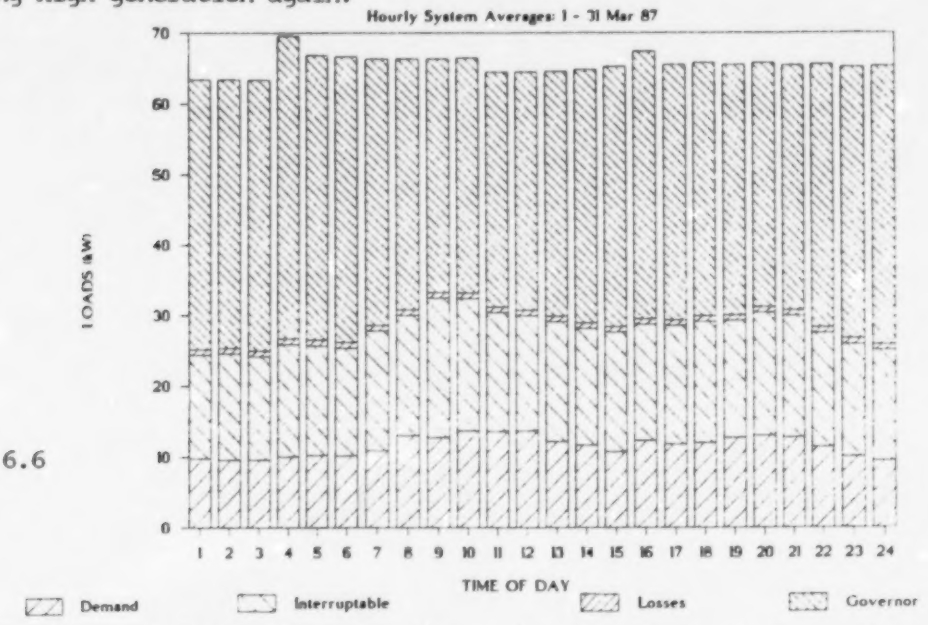


Figure 6.6

The time of day analysis on the system for Mar 1-31 1987, Figure 6.6, shows the expected demand peaks at 10:00 to 12:00 and at 8 o'clock that is close to "typical". The lack of a peak before 18:00 is probably due to the lack of electric stoves. Interruptible loads were almost constant, indicating a high and constant demand for these heating loads.

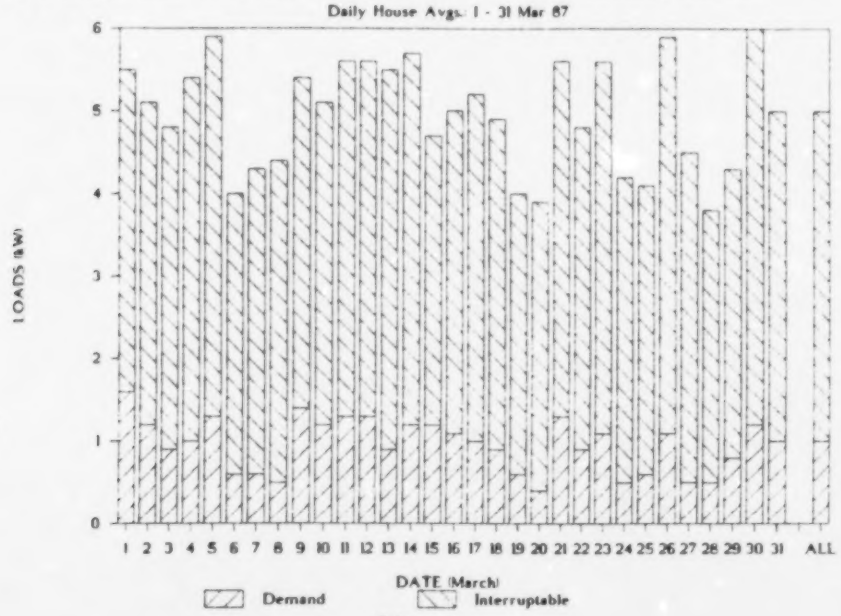


Figure 6.7

The Daily House Average, Figure 6.7, shows a number of periods of very low load, which were probably due to the owners being away. The interruptible loads are fluctuating without pattern but do tend to drop at the same time as when the demand loads are low, as would be expected.

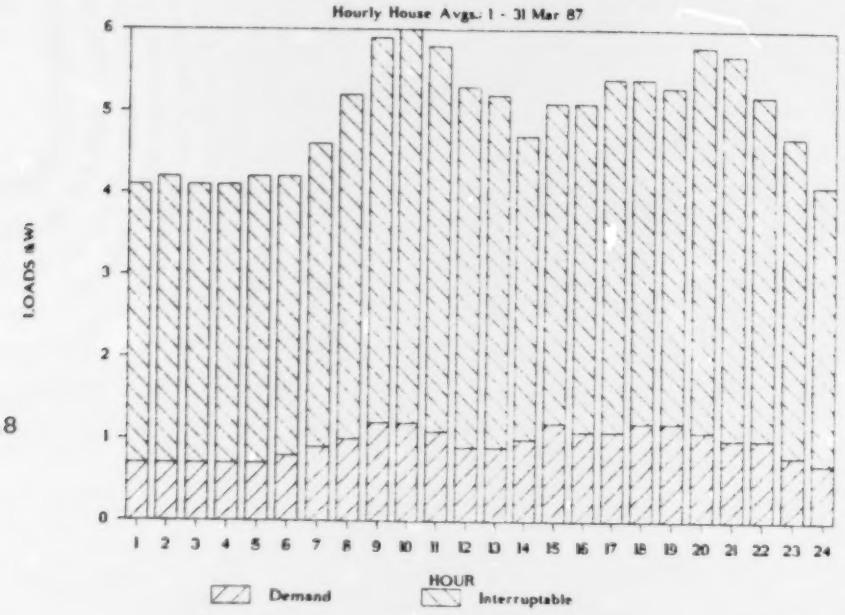


Figure 6.8

The 24 hour average profile of the house, Figure 6.8 shows a clear daily variation. The demand loads, mainly lights and small appliances show peaks at 9:00 to 10:00 and at 18:00 to 19:00. The space heating loads were almost certainly on all the time, but the dryer, hot water and dishwasher showed up as a daily variation peaking at 10:00 and 20:00 as might be expected to be typical. Sufficient power for all loads was available at all times so this data provides a reasonably typical case of how much power and energy can be managed at this time of year in a typical household.

The Daily House Average for Apr 22-May 9, Figure 6.9, shows the warming trend into summer having an impact on the interruptible heating loads, especially after the first of May. Since there are no demand heating loads, no decrease in demand is evident during the same period. From this trend, the expected decrease in managed energy, due to warmer weather in the summer, is confirmed.

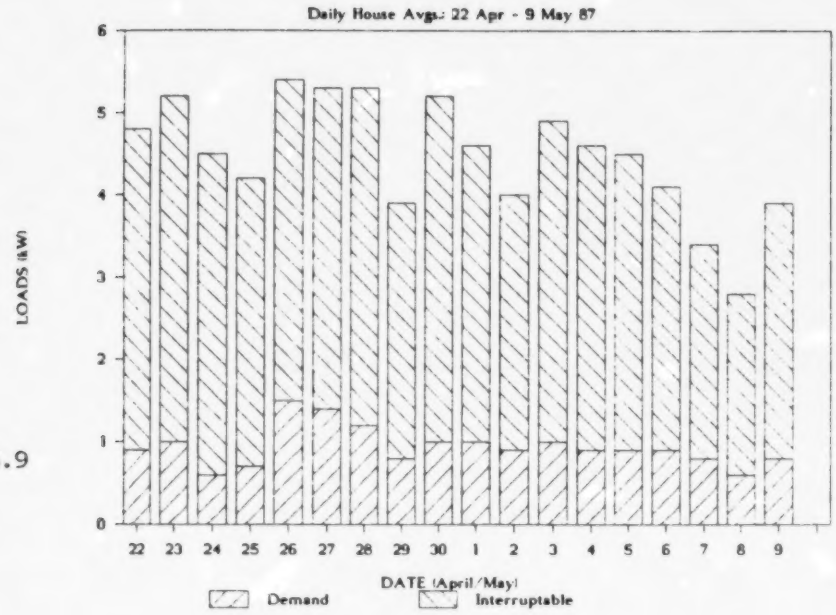


Figure 6.9

6.1.3 Summer - High Generation, Low Load Analysis

This data is from the first half of September 1987.

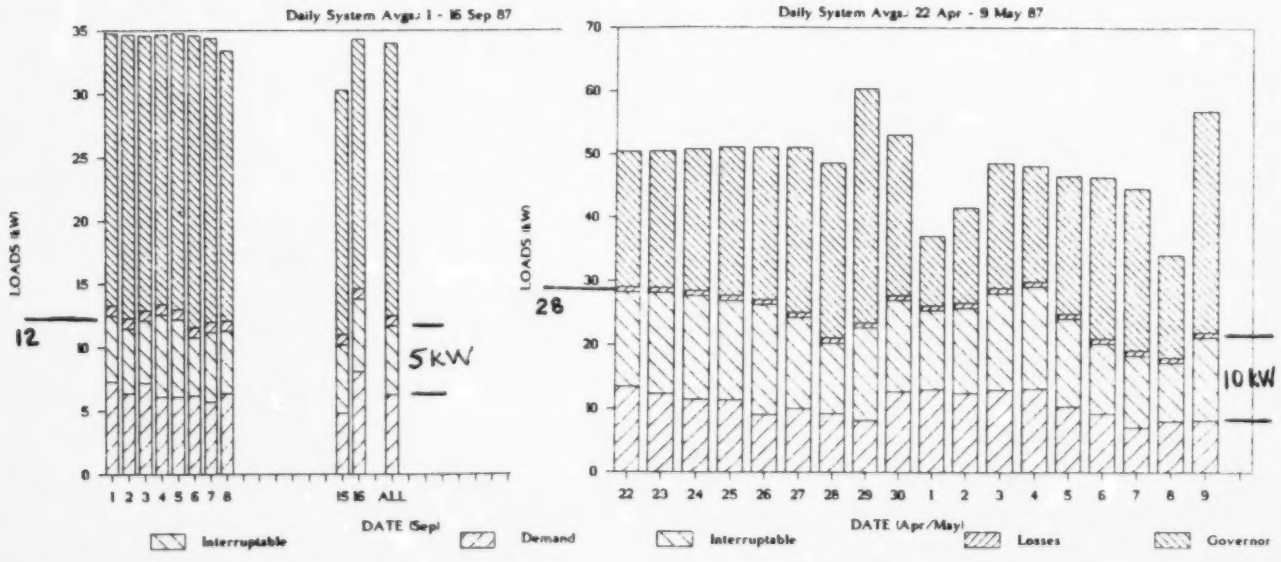


Figure 6.10

Comparing the Daily System Averages of September 1-16, Figure 6.10 on the left hand side, with previous data for April 22-May 9, on the right side, the only essential difference is the reduction in the amount of managed loads, from over 10 kW previously, to less than 5 kW.

6.1.4 Average kWhrs Moved from Peak Periods to Off-Peak Periods

This data was not available for two reasons:

1. When power output was high, there was always sufficient power for loads. No shifting was necessary.
2. When power output was low enough to require load management, there were sufficient managed heating loads requiring power such that the managed loads always used up all the power effectively available, no shifting could be seen. Instead, the power was transferred between priorities of managed loads, and this could not be recorded by the installed monitoring equipment.

The variation in streamflow and hence power output was much greater over the year than the variation in loads. In addition, the time of greatest loads, winter - for heat, was the time of least available power, ie the system was mis-matched.

6.1.5 Typical Daily Profiles for Demand and Interruptible Loads

The house data is most useful for this purpose.

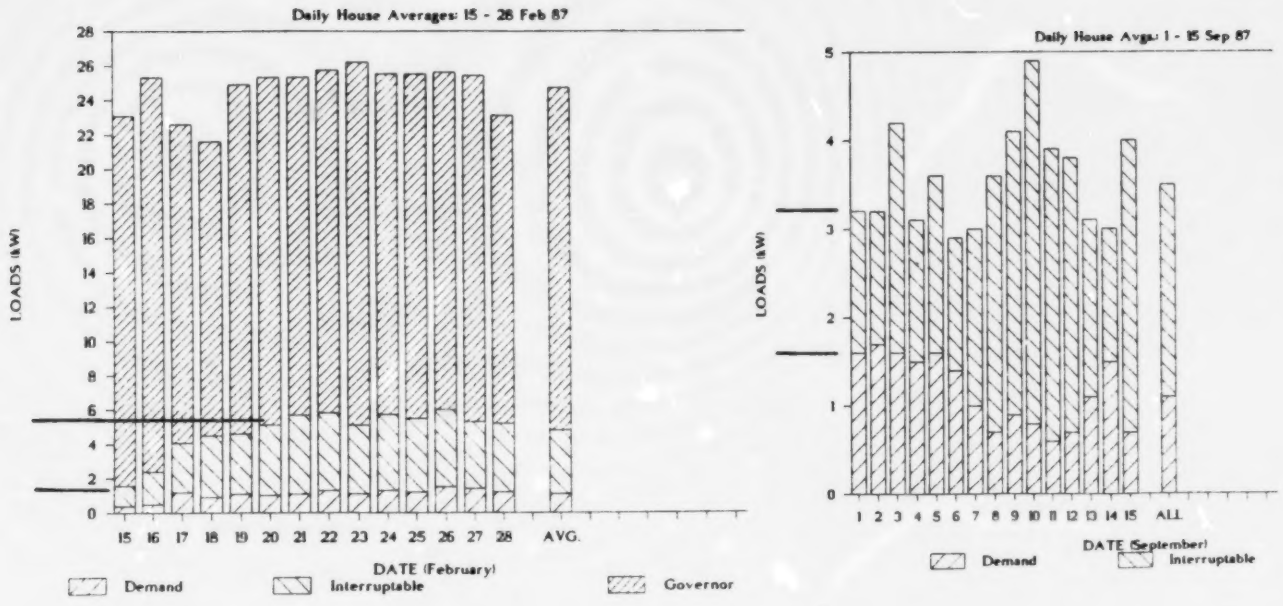


Figure 6.11

The House data for February provided Winter data, and the House data for early September provide Summer data. This house was partially electric heated with 4 kW of baseboards, supplemented and backed-up by a wood fired furnace. At times of low output, the loads are very low, indicating that the occupants didn't need power, or intentionally turned loads off to save power.

6.1.6 Required Generator Capacity

Without load management, according to the recorded data, the required generator capacity for this installation was 35 kW, however, this does not take into proper account short term loading, for instance, from the shingle saw. These loads would be powered from the managed loads being turned off for short periods of time, hence providing 5 to 15 kW of additional capacity, without any appreciable energy deficit on the part of the managed loads.

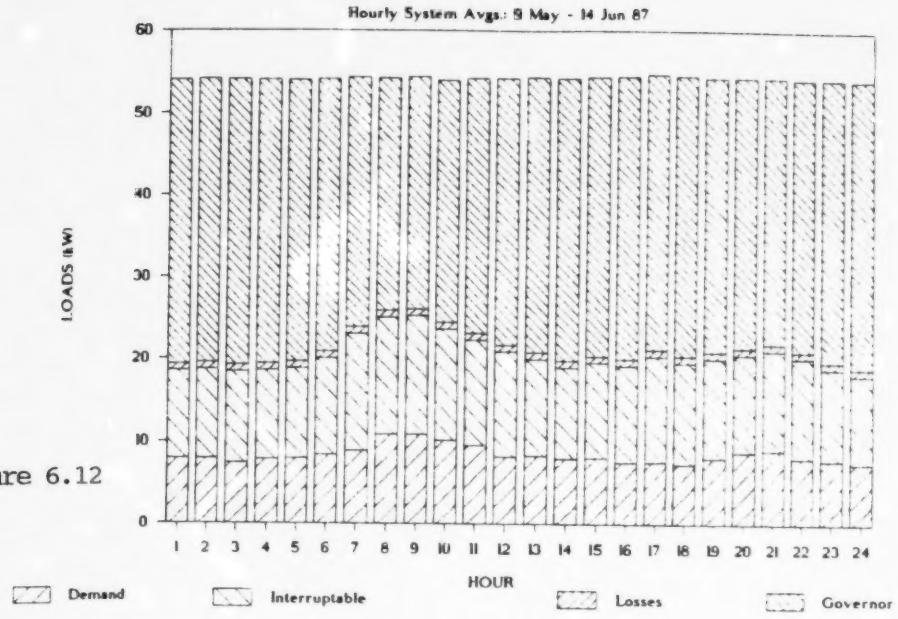


Figure 6.12

Taking into account only hourly average loads as recorded, (see Appendix B), the maximum peak system hourly load is 37 kW, and referring to the Hourly loads graph for May 1987, Figure 6.12, the average system load is less than 25 kW, while the maximum demand load is about 20 kW. Hence one could reduce the size of a hypothetical hydro plant supplying this system from 37 kW down to 20 kW without overloading problems, and with some 50% curtailment in energy to managed loads over the period represented by this graph. On the other hand, if 20 kW plant capacity were available during this time, then adding load management obtained about an average 10 kW more power from the plant than would otherwise have been available, due to overloading concerns. Over the month of May represented here, this would amount to an additional 7000 kWhrs of energy. The value of this additional energy for the one month, at utility rates of $0.05 per Kwhr, would be $350.

6.1.7 Summary of Technical Performance

The data shows the lack of dependable water flow in Cochrane Creek. At times, the system was allowed to "brown-out", run at a reduced frequency and voltage, to maintain some power throughout the system. This was during the very lowest streamflow in late winter.

At these very much reduced power levels, the installed load management system would have been required to control all loads, including lights and small appliances, to prevent overloading. Manual load management was therefore used beyond the capacity of the installed equipment. Every possible non-essential load was removed, then the voltage was allowed to drop. This community struggle with minimum power provided a graphic demonstration of how important electricity is and the lengths to which a system will be pushed to maintain it.

During 1987, when water was available, the community was unable to make full use of the power system, due to lower loads and growth rate than had been anticipated, and a lack of money to expand the loads.

Automatic water control on the turbine would have enabled continuous nozzle adjustment to match the water use to the electrical load. Manual nozzle changes did not always match the water use to the power needed, although this was not crucial as there was no water storage possible.

When sufficient water was available, and output was 30 kW or greater, a shingle mill was operated to provide employment and income. The power surges into the mill forced sufficient loads to turn off to allow the full operation of the saw.

Only hourly average data were recorded. Peak, instantaneous loading was not recorded so that short-term heavy loads, as from the shingle mill, were not available. These short term peak loads provide one of the best operating circumstances for load management since the system can unload very quickly to supply the necessary peak current required. On an average basis, the amount of energy supplied to the managed loads is not greatly

affected. Under these circumstances, the capacity of the generator required to supply almost the exact same energy to the exact same loads can be greatly reduced by load management, ie a much smaller system is possible.

6.2 Financial

The value of the electricity produced is considerable. During 1987, the average load was about 16 kW. The water-limited winter output of 9 kW or less tends to distort the average. However, at diesel fuel prices of about $.30/litre, (or 10 cents/kWh), this electricity would have cost $13,500 in diesel fuel, or about $1000 per month. Thus for an installed price of $30,000 the small hydro system will pay for itself in less than three years. When fuel prices increase, the community is protected and there is power available to expand.

The value of the unused electricity is considerable. For example, during March, although 70 kW output was available, only 30 kW was used. Over the year this unused electricity amounted to over 160,000 kWh. At diesel fuel prices of $.30/L, or 10 cents/kWh, this could have been used and would be worth $16,000. Even at 5 cents/kWh, the provincial utility price, it would have been worth $8,000.

Given the streamflow-limited output, the load management equipment would have enabled, over a full year, about 10 kw of "managed" power from April to September, plus 5 kW in March and October. The annual value of this managed power at 10 cents/kWh would be $4,000. In addition, the load management equipment would have enabled a smaller hydro generator, and attendant cost savings. This "hypothetical" plant could be re-sized from the 43 kw maximum load to about 25 kW maximum demand (without the shingle mill), or almost one-half the size. At a cost savings of perhaps 1/3 of the $30,000 the capital savings would have been about $10,000, or 2/3 of the cost of the load management equipment.

In Rendell Creek Ranch's case, where the real output peaked at 70 kw, the system could have been sized down from the 150kW capacity to about 35kW (with the shingle mill) by using the load management system. The capital savings on the hydro system by downsizing from 150 kW to 35 kW would have been perhaps 50% (or more), or about $15,000. This is roughly the cost of the load management equipment. Such a system would have been much easier to install with smaller and lighter components.

Appendix A Load Management Principles

Energy management (also known as Load Management or Demand Control) is most often used to limit the peak demand for electric energy by large buildings and similar facilities that use appreciable amounts of utility power. The advantage of reducing the magnitude of these peaks is that utilities charge their larger customers for what is called a "demand" charge, as well as the energy charge per kilowatt hour that most utility customers are familiar with. This demand charge is based on the cost of the equipment required to deliver that "peak" or maximum quantity of power, right from the generation equipment all the way to the customer's connection.

The equipment that provides this form of management will be referred to as "utility load management" or "ULM" for short. The equipment required to provide ULM will usually consist of a current measuring device at the power entrance to the building; a monitoring unit that receives the signal from the current measuring device; and relays, installed on interruptible loads, that are controlled from the monitoring device.

Small systems are even more sensitive to the cost of supplying peak demand than large utilities. They lack the diversity of loads that utility size brings. Increasing the size of a generator on a small system is expensive, so small systems tend to be limited in capacity. The specific case of hydroelectric plants without water storage, (i.e. run-of-the-stream) is even more problematic, since the amount of water available varies and becomes the limiting capacity factor, regardless of the capacity of the generator and turbine.

Controlling loads based on a preset maximum demand, as is performed by ULM systems, has some disadvantages when used on a small system. First of all, the response time of these systems may be too slow for a small system, which can be overloaded in a second or so. Secondly, the limitation of small systems is usually power, not current as is typically measured by ULM equipment, and the two are not precisely the same thing. Also, the power

should be measured right at the powerhouse, which may not be convenient, and the preset adjustments on ULM equipment will not automatically adjust for changing water availability, which is often the case with run-of-the-stream hydro turbines.

The value of some form of load management is nevertheless great for hydro turbines. Once a certain size generator is installed, or a certain amount of water is available, the cost of satisfying a peak demand is very low if below this limit, but severe if above, since in the later case the system will be overloaded, either resulting in a brown-out or a shut-down.

The type of Load management equipment that was installed at Rendell Creek Ranch as part of this study, did not have any predetermined peak demand control. This equipment determines permissible demand levels by monitoring the system frequency as the load is gradually increased, and stopping just short of the demand point at which the generator becomes overloaded. This process of loading and monitoring is continuous and is designed to adapt to varying generator capacity, water availability, or uncontrolled loads switched elsewhere on the system. The equipment for load management is also designed to be fast enough to remove loads from an overloaded generator before the system collapses, unlike most utility energy management equipment, where speed is much less important.

RENDELL CREEK LOAD MANAGED HYDRO SYSTEM
1987 Monitored Results

********** UNCORRECTED **********						********** SYSTEM **********				******** HOUSE **********			GOVERNOR
********** SYSTEM ****** ***** HOUSE *****						COMMUNITY			GENERATOR	TOTAL	DEMAND		
COMMUNITY		GENERATOR	TOTAL	DEMAND	DATE PST	TOTAL	DEMAND	INTERPT.	OUTPUT	LOADS	LOAD	INTERPT.	
TOTAL	DEMAND	OUTPUT	LOADS	LOAD									
149	8	249	1191	25	17-May 100	21.7	9.6	12.1	53.1	3.0	0.7	2.2	32.5
151	5	248	1453	24	17-May 200	22.0	8.0	14.0	52.9	3.6	0.7	2.9	32.1
145	5	249	1191	25	17-May 300	21.1	8.0	13.1	53.1	3.0	0.7	2.2	33.1
142	4	248	1161	24	17-May 400	20.7	6.4	14.3	52.9	2.9	0.7	2.2	33.4
139	7	248	1096	24	17-May 500	20.2	11.2	9.0	52.9	2.7	0.7	2.0	33.4
145	4	247	1151	25	17-May 600	21.1	6.4	14.7	52.7	2.9	0.7	2.1	32.8
159	6	248	1674	51	17-May 700	23.1	9.6	13.5	52.9	4.2	1.5	2.7	30.9
150	5	247	1726	60	17-May 800	21.8	8.0	13.8	52.7	4.3	1.7	2.6	32.0
177	7	248	1892	33	17-May 900	25.7	11.2	14.5	52.9	4.7	1.0	3.8	28.4
141	5	248	1509	34	17-May 1000	20.5	8.0	12.5	52.9	3.8	1.0	2.8	33.4
136	5	249	1239	33	17-May 1100	19.8	8.0	11.8	53.1	3.1	1.0	2.1	34.3
151	4	249	1837	40	17-May 1200	22.0	6.4	15.6	53.1	4.6	1.2	3.4	32.5
150	5	250	2000	32	17-May 1300	21.8	8.0	13.8	53.3	5.0	0.9	4.1	32.7
154	4	251	2807	34	17-May 1400	22.4	6.4	16.0	53.5	7.0	1.0	6.0	32.5
158	5	252	2259	35	17-May 1500	23.0	8.0	15.0	53.8	5.6	1.0	4.6	32.0
180	4	253	2352	34	17-May 1600	26.2	6.4	19.8	54.0	5.9	1.0	4.9	29.4
176	6	254	3421	62	17-May 1700	25.6	9.6	16.0	54.2	8.5	1.8	6.7	29.9
145	5	252	1900	34	17-May 1800	21.1	8.0	13.1	53.8	4.7	1.0	3.7	33.8
157	14	220	1735	38	17-May 1900	22.8	22.4	0.4	46.9	4.3	1.1	3.2	24.1
184	9	251	1601	33	17-May 2000	26.8	14.4	12.4	53.5	4.0	1.0	3.0	27.8
217	9	255	1731	34	17-May 2100	31.6	14.4	17.2	54.4	4.3	1.0	3.3	24.3
179	7	255	1760	22	17-May 2200	26.0	11.2	14.8	54.4	4.4	0.6	3.7	29.6
170	6	254	1572	21	17-May 2300	24.7	9.6	15.1	54.2	3.9	0.6	3.3	30.7
170	6	254	1552	21	17-May 2400	24.7	9.6	15.1	54.2	3.9	0.6	3.3	30.7
168	7	254	1683	25	18-May 100	24.4	11.2	13.2	54.2	4.2	0.7	3.5	30.9
176	6	253	1768	21	18-May 200	25.6	9.6	16.0	54.0	4.4	0.6	3.8	29.7
165	6	254	1552	21	18-May 300	24.0	9.6	14.4	54.2	3.9	0.6	3.3	31.4
165	5	253	1758	21	18-May 400	24.0	8.0	16.0	54.0	4.4	0.6	3.8	31.3
158	6	253	1579	21	18-May 500	23.0	9.6	13.4	54.0	3.9	0.6	3.3	32.1
152	8	252	1554	20	18-May 600	22.1	12.8	9.3	53.8	3.9	0.6	3.3	32.4
206	6	254	1939	34	18-May 700	30.0	9.6	20.4	54.2	4.8	1.0	3.8	25.9
241	11	254	1519	30	18-May 800	35.1	17.6	17.5	54.2	3.8	0.9	2.9	20.6
236	11	255	2447	28	18-May 900	34.3	17.6	16.7	54.4	6.1	0.8	5.3	21.5
258	9	253	3439	52	18-May 1000	37.5	14.4	23.1	54.0	8.6	1.5	7.1	18.4
226	8	255	3274	45	18-May 1100	32.9	12.8	20.1	54.4	8.1	1.3	6.9	23.2
198	7	254	2710	47	18-May 1200	28.8	11.2	17.6	54.2	6.7	1.4	5.4	26.9
176	6	252	2788	75	18-May 1300	25.6	9.6	16.0	53.8	6.9	2.2	4.8	29.5
197	6	253	2662	60	18-May 1400	28.7	9.6	19.1	54.0	6.6	1.7	4.9	26.9
183	7	253	2685	33	18-May 1500	26.6	11.2	15.4	54.0	6.7	1.0	5.7	28.6
189	8	253	2301	47	18-May 1600	27.5	9.6	17.9	54.0	5.7	1.4	4.4	28.0
210	8	253	2740	41	18-May 1700	30.5	9.6	20.9	54.0	6.8	1.2	5.6	25.2
194	5	254	3398	44	18-May 1800	28.2	8.0	20.2	54.2	8.5	1.3	7.2	27.7
183	6	254	2673	50	18-May 1900	26.6	9.6	17.0	54.2	6.7	1.4	5.2	29.0
179	8	253	2700	38	18-May 2000	26.0	9.6	16.4	54.0	6.7	1.1	5.6	29.3
196	8	252	2675	39	18-May 2100	28.5	9.6	18.9	53.8	6.7	1.1	5.5	26.8
186	6	252	2596	34	18-May 2200	27.1	9.6	17.5	53.8	6.5	1.0	5.5	28.2
166	6	252	1760	22	18-May 2300	24.1	9.6	14.5	53.8	4.4	0.6	3.7	30.8
156	5	252	1488	21	18-May 2400	22.7	8.0	14.7	53.8	3.7	0.6	3.1	32.3

data questionable/missing

SAR engineering

Appendix C - Glossary

Capacity - the "rated size" or designed size of an electricity generating system. Generally this is the size of the generator attached to a turbine or diesel engine, at .8 power factor. Capacity of small hydro systems may be limited by the amount of water in the stream. Measured in kW or 1 kilowatts.

Demand - this is electricity that is essential, such as lights and wall outlets, and is highest priority or importance. Fridges may also be "demand loads", ie electricity must always be available, even if not always on.

Interruptible - electrical uses such as water heat or building heat then could be switched off without seriously interfering with a lifestyle. The length of off time may be short or if there is another source of energy such as wood stove, building heat could be turned off for extensive duration.

Loads - uses for electricity. Lights, fridges, freezers, electric water heaters are 'loads'.

Load dump - usually an immersion or water heater to use up electricity in a controlled manner. An electronic governor allows a generator to operate at full capacity, then sends unused electricity to the load dump. This gets turned into heat and can be useful for hot tubs, greenhouses etc when the useful loads are low and there is much "waste" or load dump.

Load Management - control of the timing of loads connected to reduce the maximum load, and hence the size of the generator required. This could be manual - not turning on an electric stove while the clothes dryer is on, or could be automatic and electronic. Too much load will 'overload' and cause a generator to slow down, and eventually burn out.

With seasonal variation in streamflow, small hydro systems can benefit from load management by matching the available power to the loads with the highest priority.

Peak - the maximum load imposed. If all loads are simultaneously on, the peak would be the sum of all the loads. Generally, the peak load from a house is actually half to two thirds the total potential load.

Plant - a generator, diesel or small hydro.

Run-of-the river - a small hydro system without water storage and hence one which cannot draw down a reservoir to meet peak loads.